DR Technologies, Strategies and Case Studies

March 3, 2011

Mary Ann Piette, Sila Kiliccote, Dave Watson, Rish Ghatikar

Research Director, DRRC
Deputy, Building Technologies Department
Staff Scientist, LBNL
MAPiette@lbl.gov

Demand Response Research Center

Concepts and Terminology
Levels of Automation in DR

- Manual DR – Building operators manually turn off switches and change set points at each device
  - Labor intensive
  - Poor reliability, repeatability
  - Day ahead notification req'd
- Semi-Automated DR - pre-programmed DR strategies initiated by a person via centralized control system
  - Better reliability, repeatability
  - Hours ahead notification req'd
- Fully-Automated DR - pre-programmed DR strategies automatically initiated upon receipt of remote signal
  - Most reliable & repeatable
  - Sheds can occur within seconds

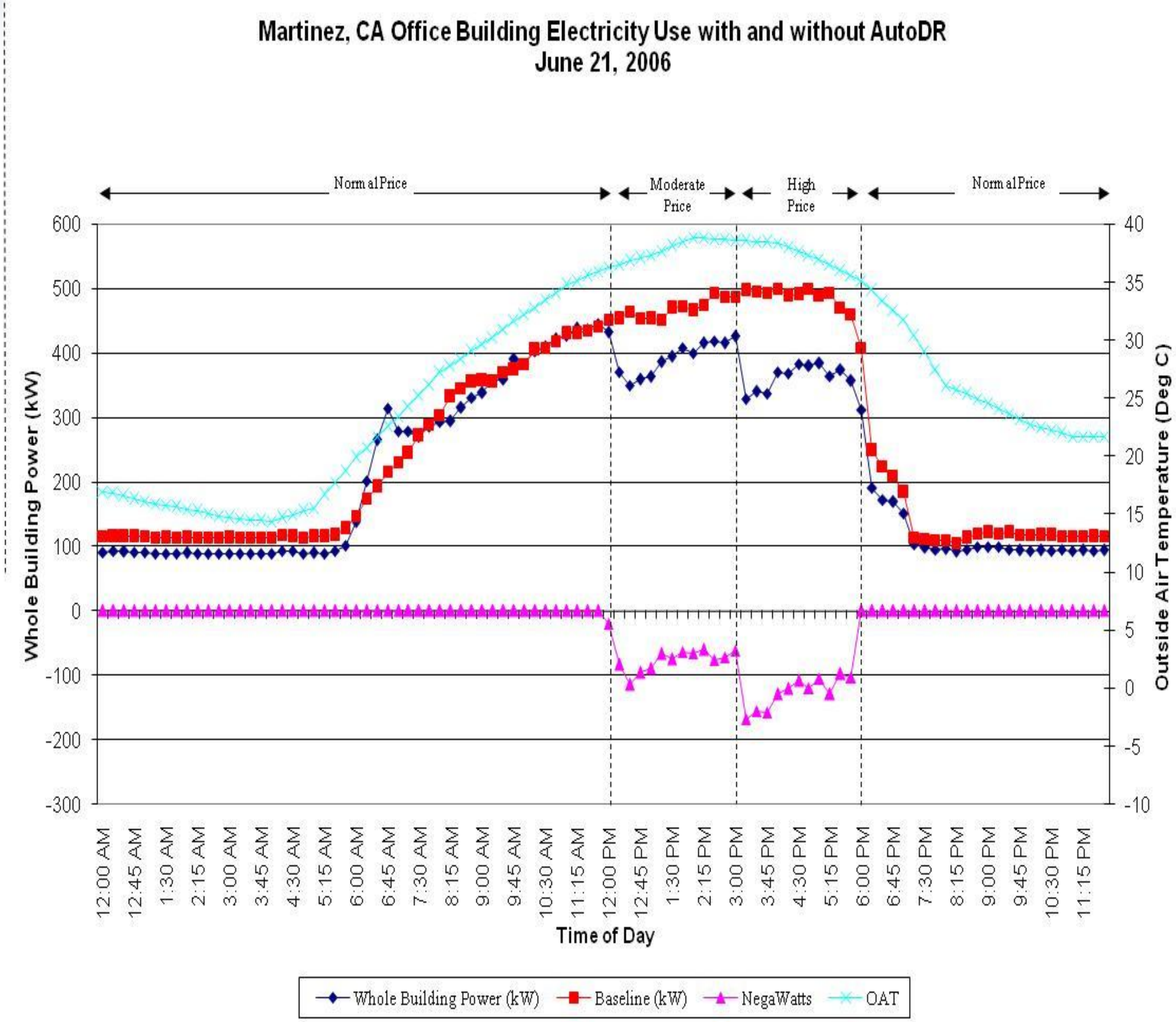
BERKELEY LAB

HVAC - Global Temperature Adjustment

- GTA based DR strategies can be used:
  - Manually by building operators
  - Automatically based on remote signals
- GTA Signal from central EMCS server to all space temperature controllers throughout the facility.
- GTA well suited for HVAC equipment such as:
  - VAV boxes
  - Fan coil units
  - CAV multi-zone temperature control valves
  - heat pumps & DX package units.
- Heating setpoints should remain the same or be reduced during GTA mode.

Berkeley Lab

Auto-DR in 130,000 ft² County Office Current Practice



DR Field Tests from 2003, 2004 & 2005

GSA, Phillip Burton Federal Building
Federal (San Francisco)
Office
1,424,000 ft²
2,130 kW peak

GSA, Ronald Dellums Federal Building
Federal (Oakland)
Office
978,000 ft²
4,100 kW peak

GSA, National Archive & Record Admin.
Federal (San Bruno)
Archive storage
238,000 ft²
280 kW peak

US Postal Service San Jose PDC
Federal (San Jose)
Process, distribution
390,000 ft²
1,630 kW peak

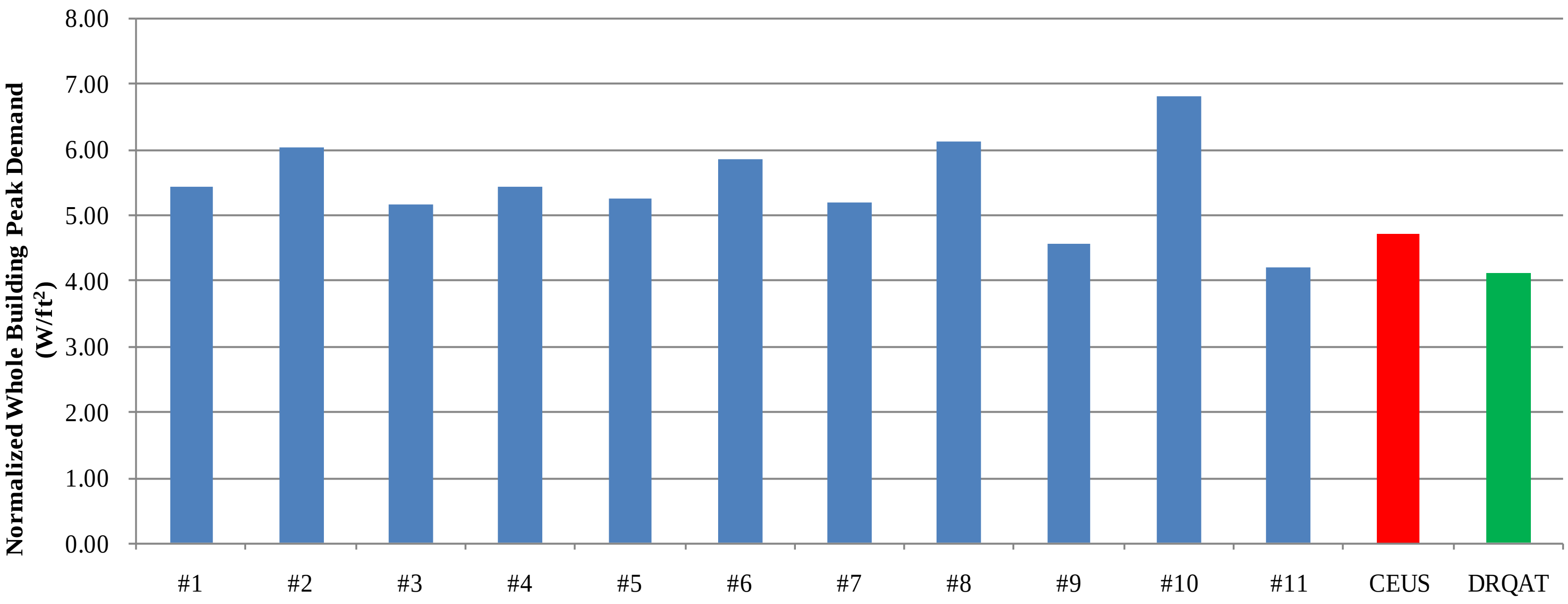
Joe Serna Jr. Cal EPA Headquarters Building
State (Sacramento)
Office
950,000 ft²
1,990 kW peak

UC Santa Barbara Davidson Library
State (Santa Barbara)
Library
289,000 ft²
1,090 kW peak

BERKELEY LAB

Typical Power Densities

- California Commercial End-Use Survey (CEUS) and eleven field test buildings (Yin et al. 2010)
- The simulation results from DRQAT are lower than field test data and CEUS, likely due to the assumed lighting densities, HVAC system efficiencies and building envelope of the prototypical building model

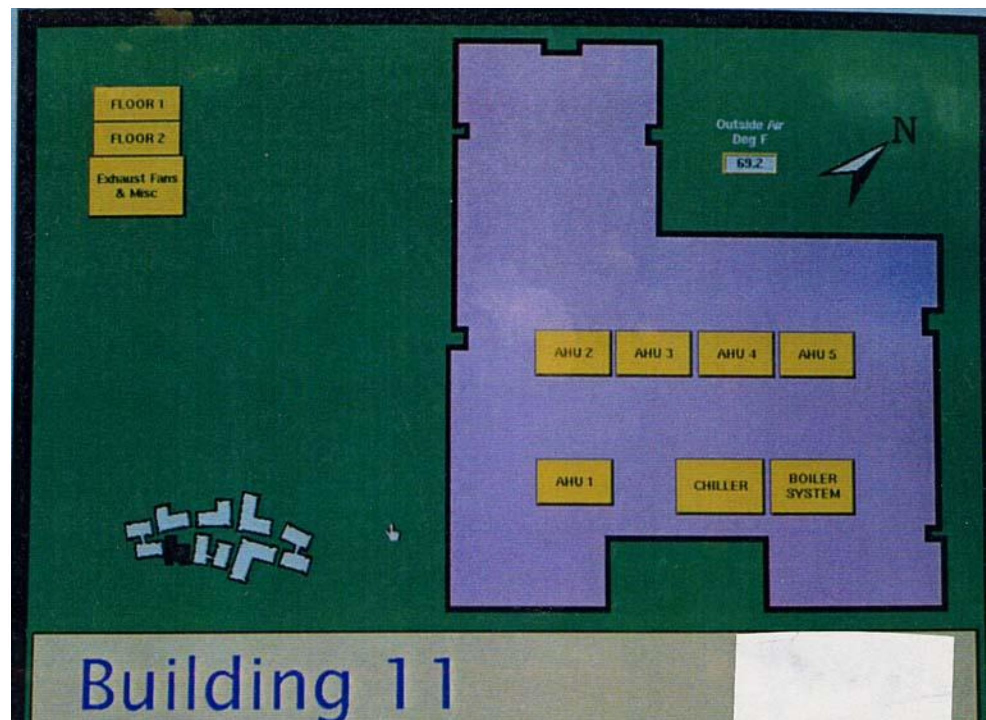


Results using GTA (2003-2005)

Site name	Area (ft^2)	Cooling Capacity (Tons)	Strategy Used	# Days of Testing	Climate Zone	Outside temperature at time of peak	Average shed (W/ft^2)*	Peak shed (W/ft^2)
GSA Oakland Federal Building	978,000	3,840	Global Temp Adjustment	4	3	88	0.30	**1.10**
Contra Costa County 2350 Arnold	131,000	240	Global Temp Adjustment	2	12	90	0.30	**0.67**
Contra Costa County 50 Douglas	90,000	240	Global Temp Adjustment	2	12	90	0.58	**1.34**
GSA Santa Rosa Federal Building	80,000	200	Global Temp Adjustment*	20	2	95	1.50	**2.40**
Sacramento County Building	80,000	180	Global Temp Adjustment*	3	12	70	0.75	**1.00**
Cisco	4,354,000	24,600	Global Temp Adjustment & other strategies	1	4	90	0.16	**0.20**
Echelon	75,000	4,800	Global Temp Adjustment & other strategies	2	4	90	0.89	**1.22**

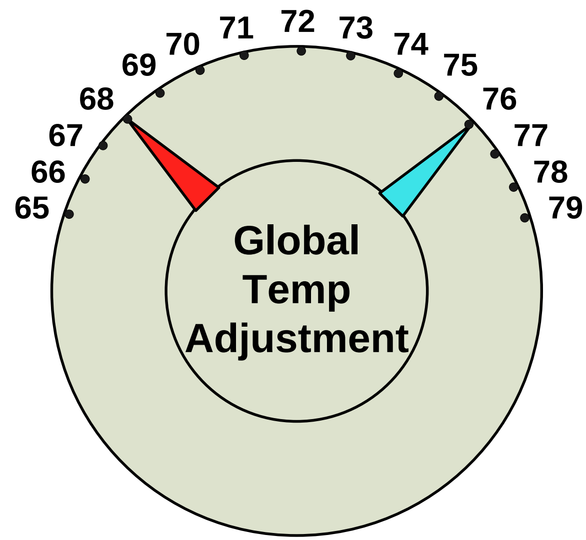
BERKELEY LAB

Typical EMCS Graphical User Interface

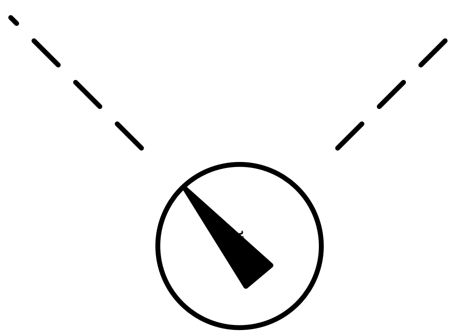


GTA – Conceptual Implementation #1 (Absolute)

Normal Mode



DR Mode



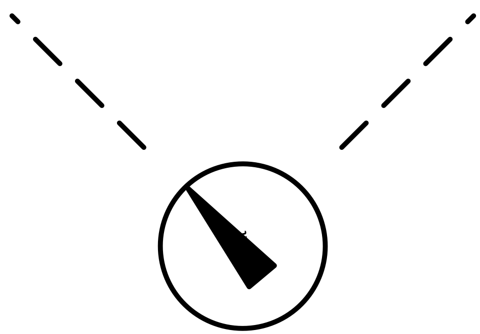
GTA – Conceptual Implementation #2 (Relative)

Normal Mode

Global Temp Adjustment
(Relative)

“Relax” each zone
by <u>**2**</u> deg.F

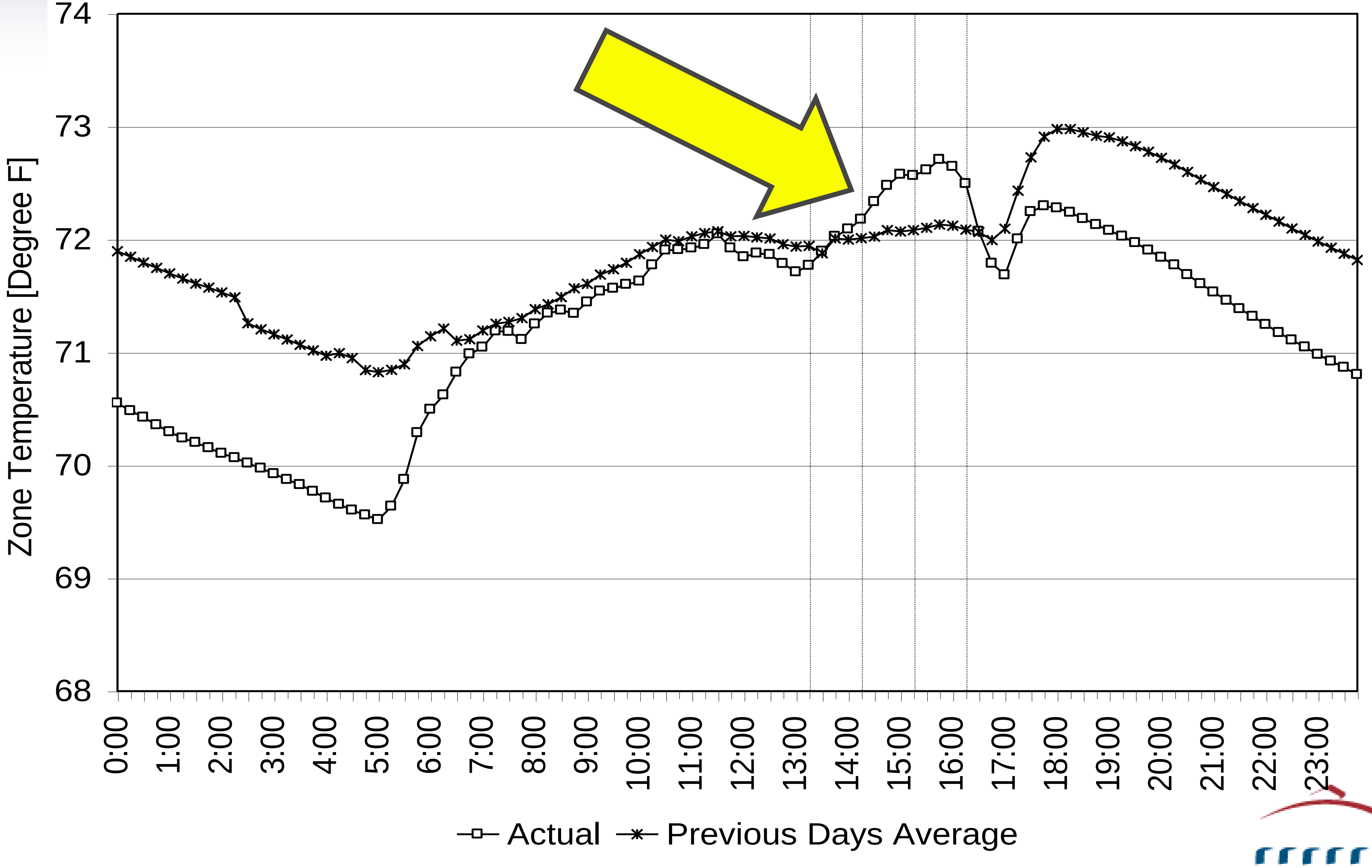
DR Mode



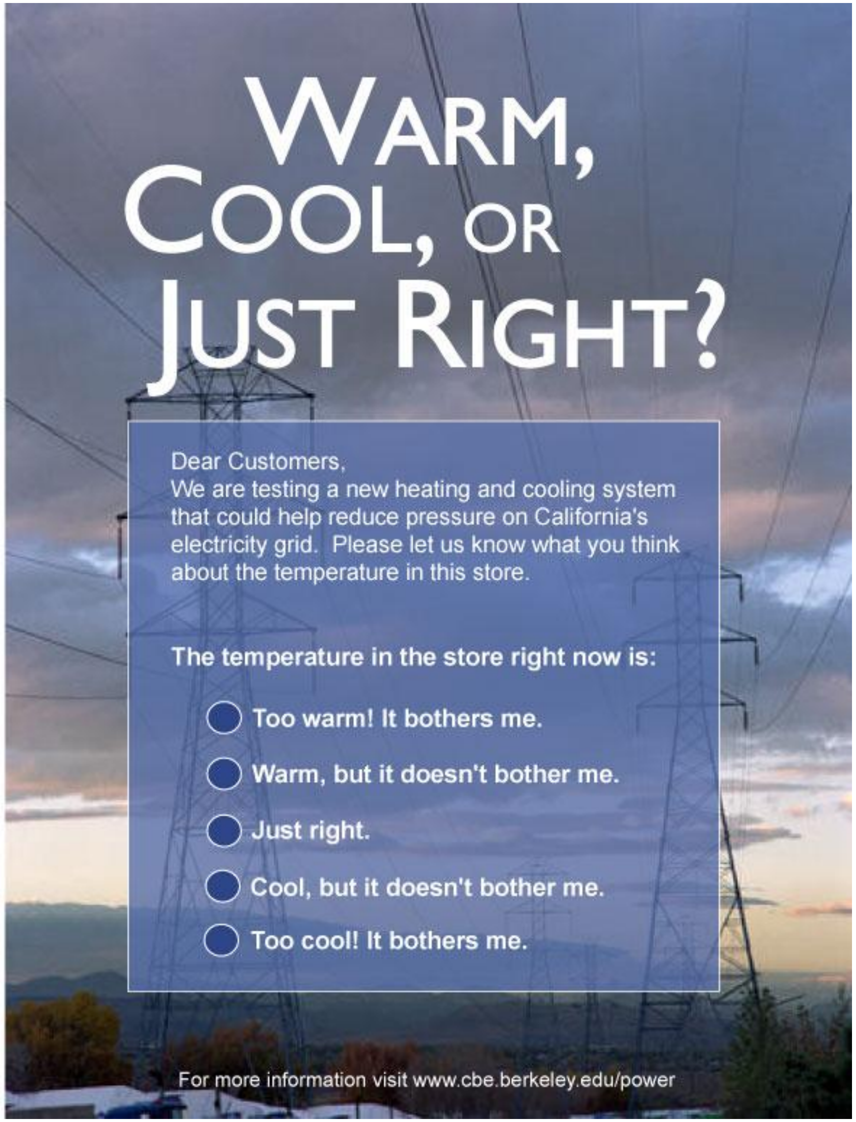
Cost to Implement GTA

- Software only – no hardware cost.
- Several (smaller) vendors already offer this feature at no extra cost.
    - Sold nationwide
- Remaining vendors can add GTA to standard product line at a low one-time cost.
- GTA can be added to existing buildings
    - Zone level DDC required
    - Programming cost $2K - $10K per site

Comfort: 1.5 deg. F° Temperature Rise at GSA (39 zone average)



Comfort: Online Tennant Survey



LBNL DR Strategies Report

•DR Control Strategies for Commercial Buildings:

DR Strategy	Global Temperature Adjustment (GTA)
Definition	Increase zone temperature setpoints for an entire facility.
HVAC type	CAV, VAV systems. Cooling by central plant or package unit DX.
System applicability	EMCS must have DDC control to the zone level. EMCS must have Global Temp Adjustment feature.
Sequence of Operation (DR)	Increase zone temperature cooling setpoints globally throughout entire facility. Zone temperature heating setpoints must remain unchanged or be reduced.
Power savings in:	Fans & Cooling systems
Efficiency potential	Permanent increase in zone temperature setpoints for some zones may be possible
Rebound Avoidance	Gradual ramp back to normal setpoints. Lock out chillers etc.
Caution	Occupant comfort. Zones will approach increased temperature setpoints at different rates.

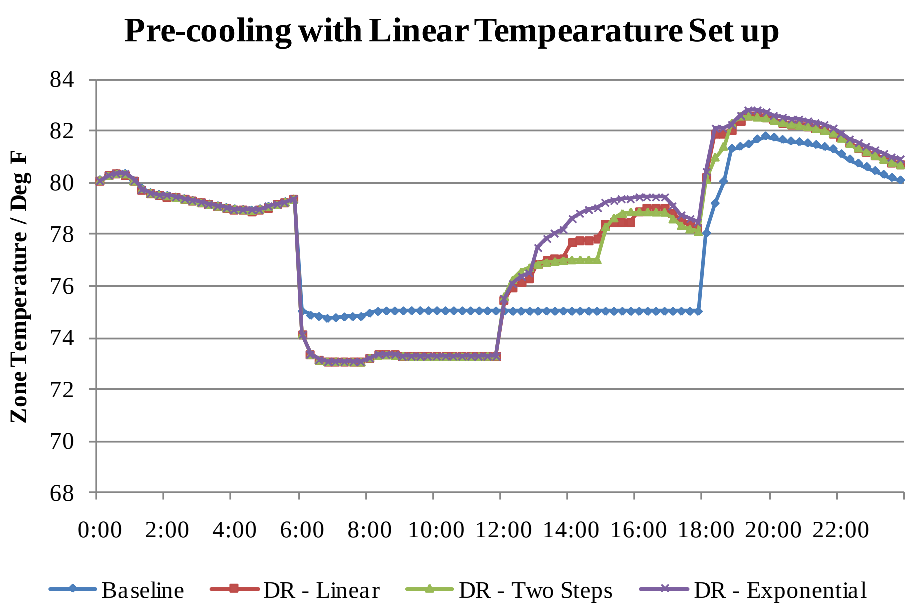
Building Control Strategies Guide and Case Studies

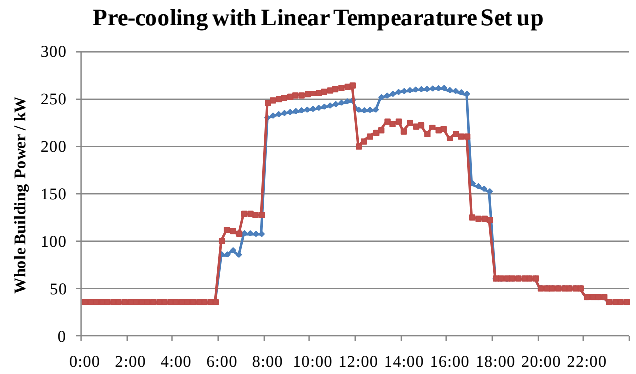
BERKELEY LAB

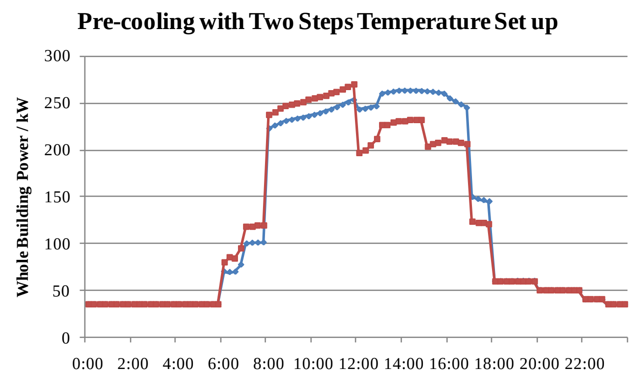
Precooling and Thermal Mass

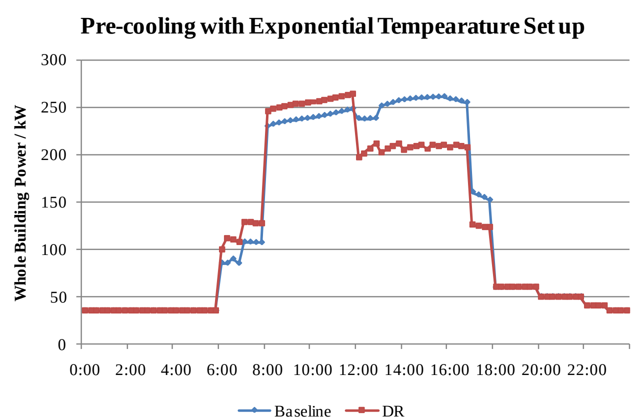
Evaluate the Effect of Control Strategies based on:

- Utility rate structure
- Peak demand savings
- Zone comfort (PPD





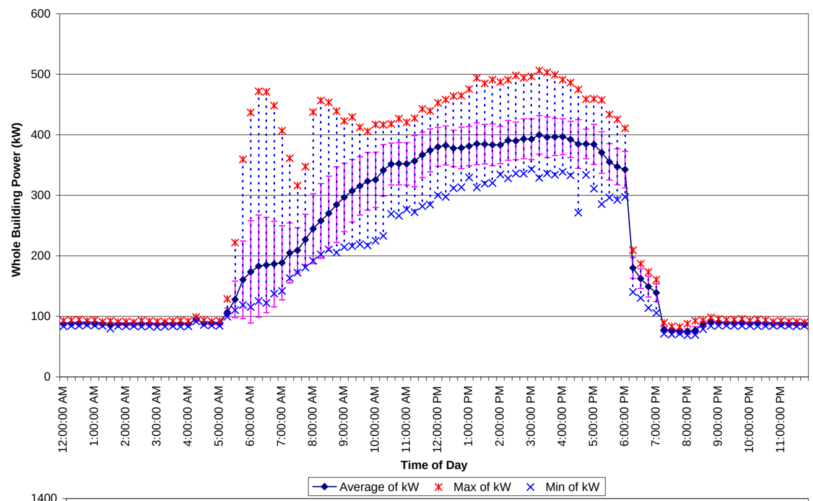


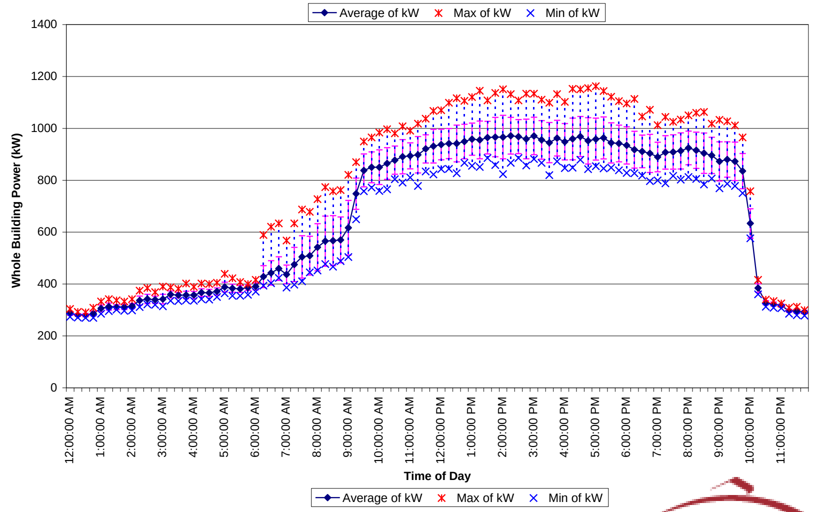


Load Statistical Summary (LSS)

LSS a plot of average, minimum and maximum points for a given range of dates.

- Refined to display Near-base load and near-high load (2.5 and 97.5 percentile values) (Price 2010)





Fan System Adjustment - Fan speed limit

- Applicable to fans with variable frequency drives (VFDs).
- Similar to duct static pressure setpoint reduction.
- Less predictable because of the open-loop nature of the control.
- Fan speed limits may be useful as part of other DR strategies such as cooling system adjustments.

Fan System Adjustment - Fan Quantity Reduction.

- Applicable to constant air volume fan systems.
- Reduce fan energy by turning fans OFF completely.
- May be useful in common areas served by multiple fans.
- Cooling energy in the fans that remain ON may increase to make up for those that are OFF.

Fan System Adjustment – Increase Supply Air temperature

- Applicable to CAV and VAV fan systems
- Saves mechanical cooling energy
  - For air handlers with cooling coils, the savings will occur at the central cooling plant.
  - For packaged DX units & heat pumps, the savings will be achieved at each unit.
- Avoid increased fan energy in VAV systems due to increased air flow
  - Prevent this effect by limiting fan speeds to prior levels

Fan System Adjustment - Cooling System Adjustment

- Applicable to Central Chiller plants & Packaged DX units & Heat Pumps.
- Most modern centrifugal, screw and reciprocating chillers have the capability of reducing demand for power:
  - Raise chilled water supply temperature setpoint
  - Limit the speed, capacity, number of stages or current draw of the chiller
  - The quantity of chillers running can be reduced in some plants

BERKELEY LAB

Lighting Based DR Strategies

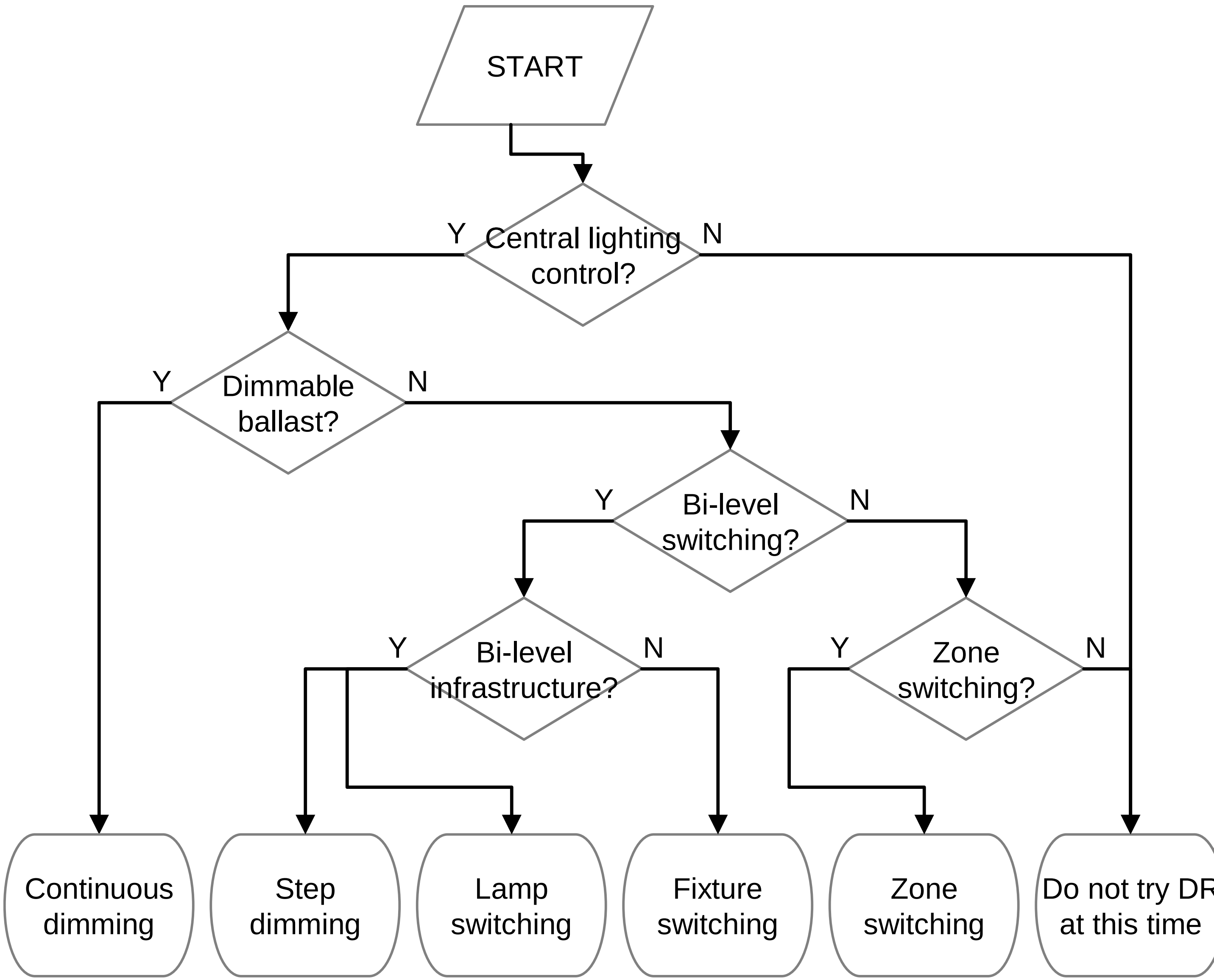
- Lighting systems offer great promise as a resource for DR shed savings
  - Lighting systems account for ~ 1/3 electric load in commercial buildings
  - Lighting has no rebound effect during the transition from DR events to normal operations
  - In California, most commercial buildings already have bi-level switching. 1/3 or 2/3 of the lights in a given office can be turn off.
  - Pre-planned automated DR strategies make sheds more repeatable and less labor intensive.
- Technical challenges:
  - Few office buildings have centralized control of lighting systems (Kiliccote, et al, 2005).
  - Buildings with centralized lighting controls are not necessarily zoned to enable reduced light levels adequate for occupancy.

Lighting Based DR Strategies

- Resolution of control is an important factor in determining the usefulness of lighting systems for DR. From highest to lowest resolution.
  - Continuous Dimming.
    - Allow light output to be dimmed from 100% to 10% (fluorescent) or 100% to 50% (HID).
    - Gradual reductions not noticeable
    - specific DR shed goals can be achieved
    - Energy efficiency benefits in addition to DR
  - Stepped Dimming, Lamp Switching, and Fixture Switching
    - 2 or 3 light levels
    - Noticeable, but manageable light levels.
    - Lighting zones must be wired to ensure that all floor space remains illuminated at reduced levels.
  - Zone Switching
    - Applicable to zones that are unoccupied, or illuminated by windows.
    - Egress light levels must be assured.

BERKELEY LAB

DR Strategies: Lighting (of)

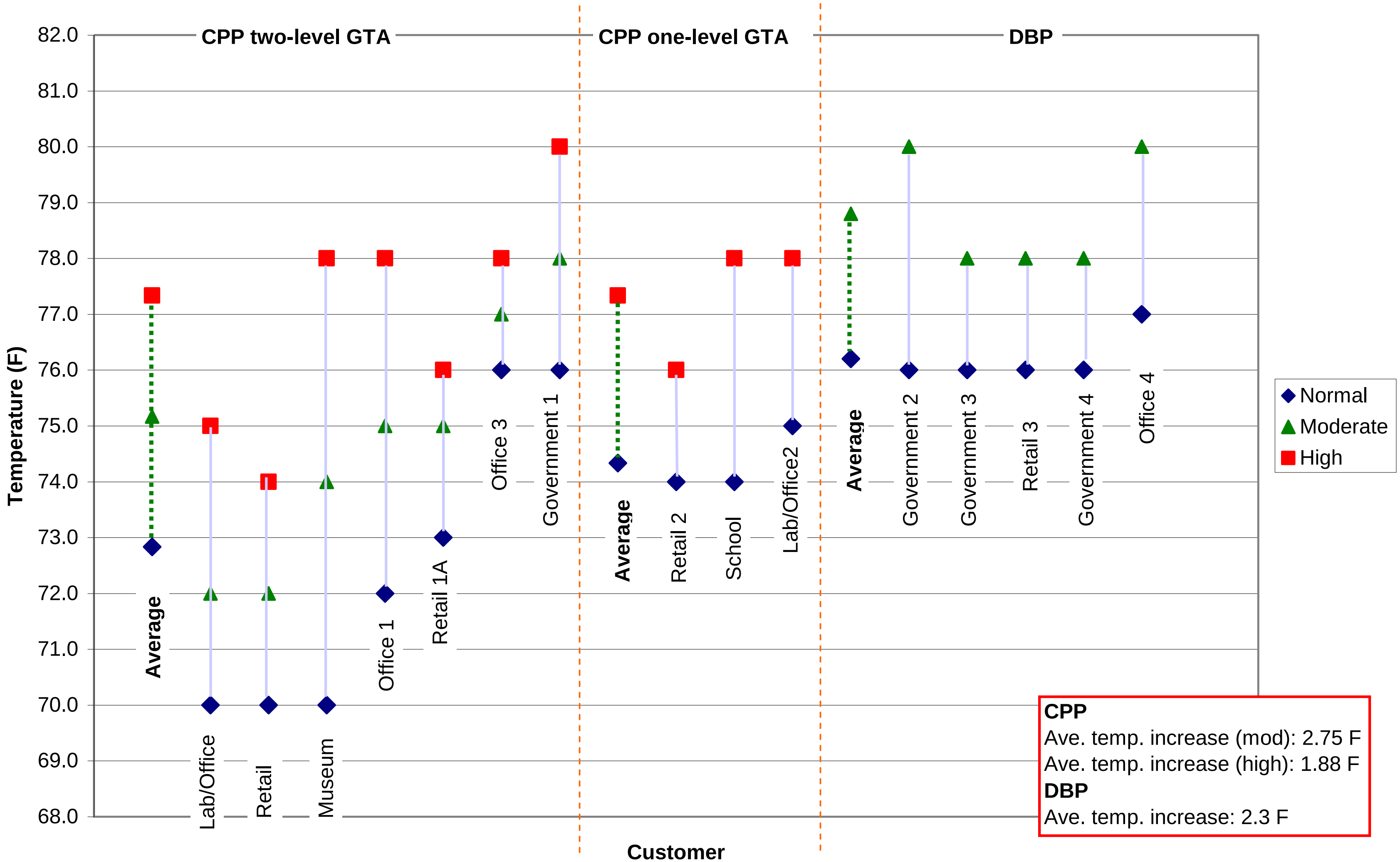


Comparison of End-Use Strategies

Global temperature reset migrated to State Energy Code

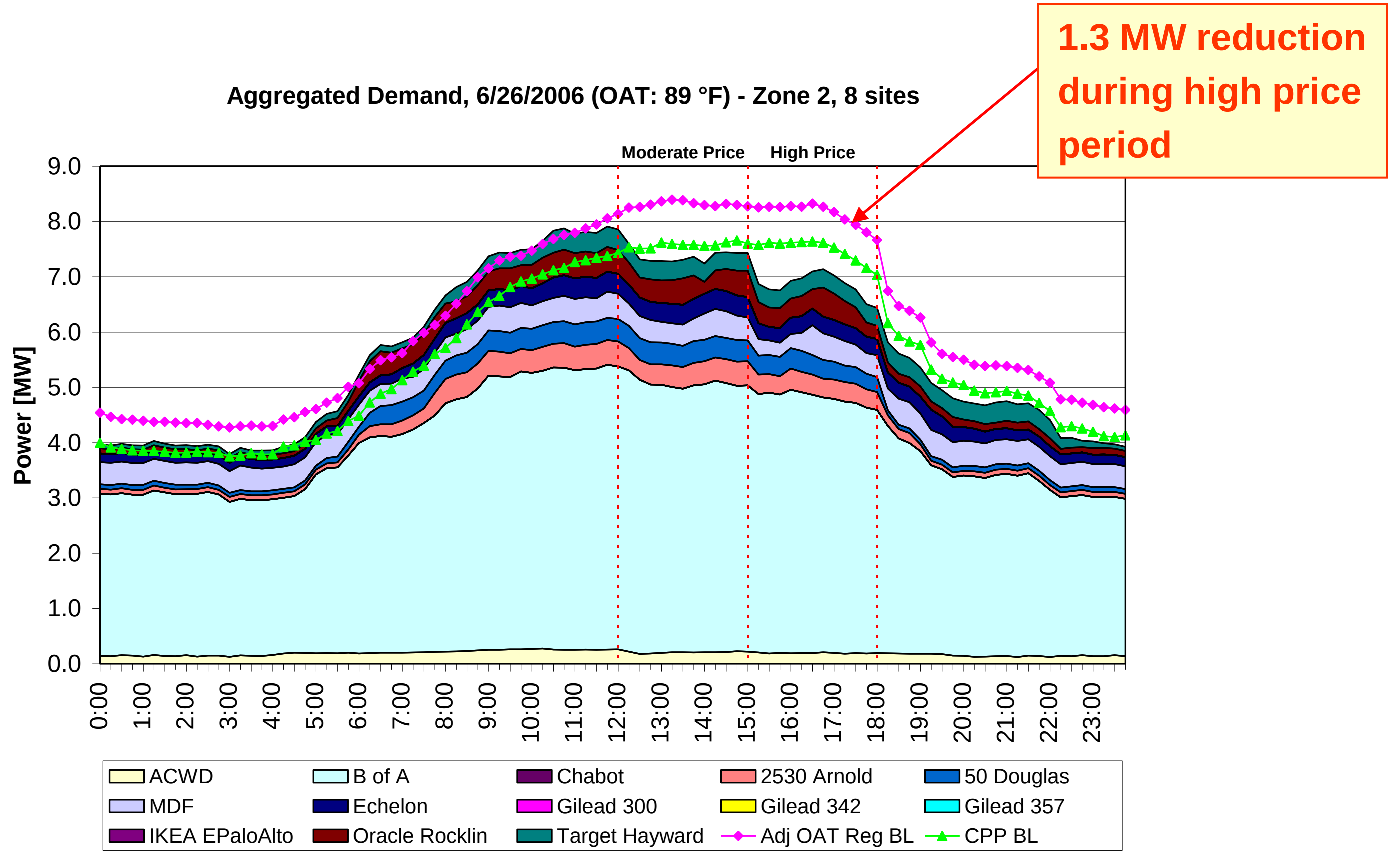
	Building use	HVAC											Lighting					Other
		Global temp. adjustment	Duct static pres.	SAT Increase	Fan VFD limit	CHW temp. Increase	Fan qty. reduction	Pre-cooling	Cooling valve limit	Boiler lockout	Slow recovery	Extended shed period	Common area light dim	Office area light dim	Turn off light	Dimmable ballast	Bi-level switching	Non-critical process shed
ACWD	Office, lab	X	X	X		X			X	X		X						
B of A	Office, data center		X	X	X	X			X									
Chabot	Museum	X						X										
2530 Arnold	Office	X									X							
50 Douglas	Office	X									X							
MDF	Detention facility	X																
Echelon	Hi-tech office	X	X	X			X						X	X	X	X		
Centerville	Junior Highschool	X						X										
Irvington	Highschool	X						X										
Gilead 300	Office			X														
Gilead 342	Office, Lab	X		X														
Gilead 357	Office, Lab	X		X														
IKEA EPaloAlto	Furniture retail	X																
IKEA Emeryville	Furniture retail	X																
IKEA WSacto	Furniture retail																	
Oracle Rocklin	Office	X	X															
Safeway Stockton	Supermarket																X	
Solectron	Office, Manufacture	X													X			
Svenhard's	Bakery																	X
Sybase	Hi-tech office														X			
Target Antioch	Retail	X					X											
Target Bakersfield	Retail	X					X											
Target Hayward	Retail	X					X						X				X	
Walmart Fresno	Retail	X															X	

Global Temperature Adjustment



CPP
Ave. temp. increase (mod): 2.75 F
Ave. temp. increase (high): 1.88 F
DBP
Ave. temp. increase: 2.3 F

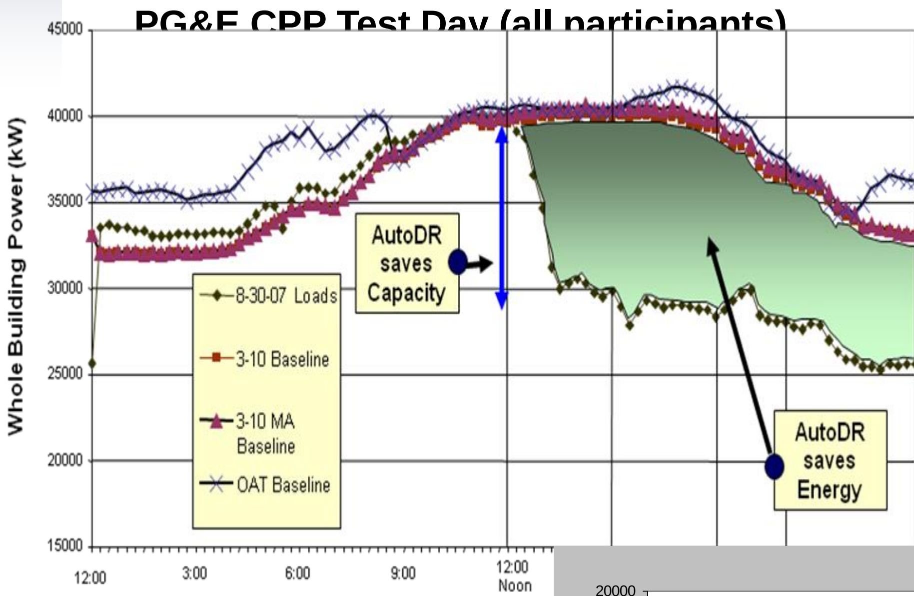
Aggregated AutoDR Results – June 26, Zone 2

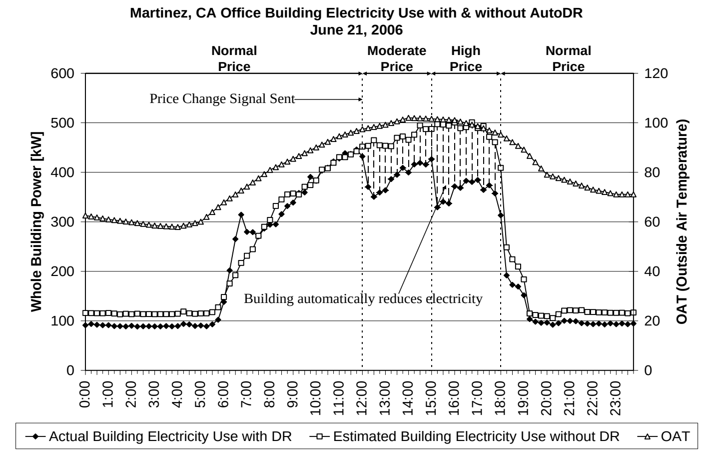


	Average kW		Average %		Average W/ft²	
	Moderate	High	Moderate	High	Moderate	High
ACWD	78	91	28%	32%	1.53	1.78
B of A	478	604	9%	12%	0.67	0.85
2530 Arnold	102	140	20%	29%	0.78	1.07
50 Douglas	57	94	13%	22%	0.63	1.04
MDF	90	155	17%	30%	0.52	0.90
Echelon	-2	80	0%	22%	-0.02	1.07
Oracle Rocklin	85	60	17%	14%	0.85	0.60
Target Hayward	59	56	15%	15%	0.45	0.43
Aggregated	946	1281	11%	16%	0.65	0.88

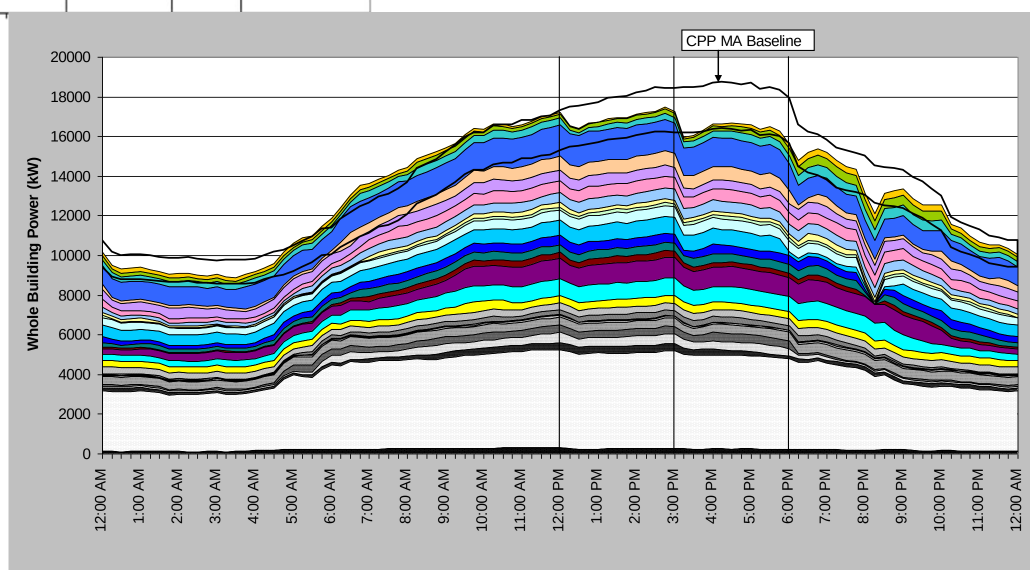
Consistent Multi-Year Field Performance Automating DR

OpenADR Application Impacts 2003-2009

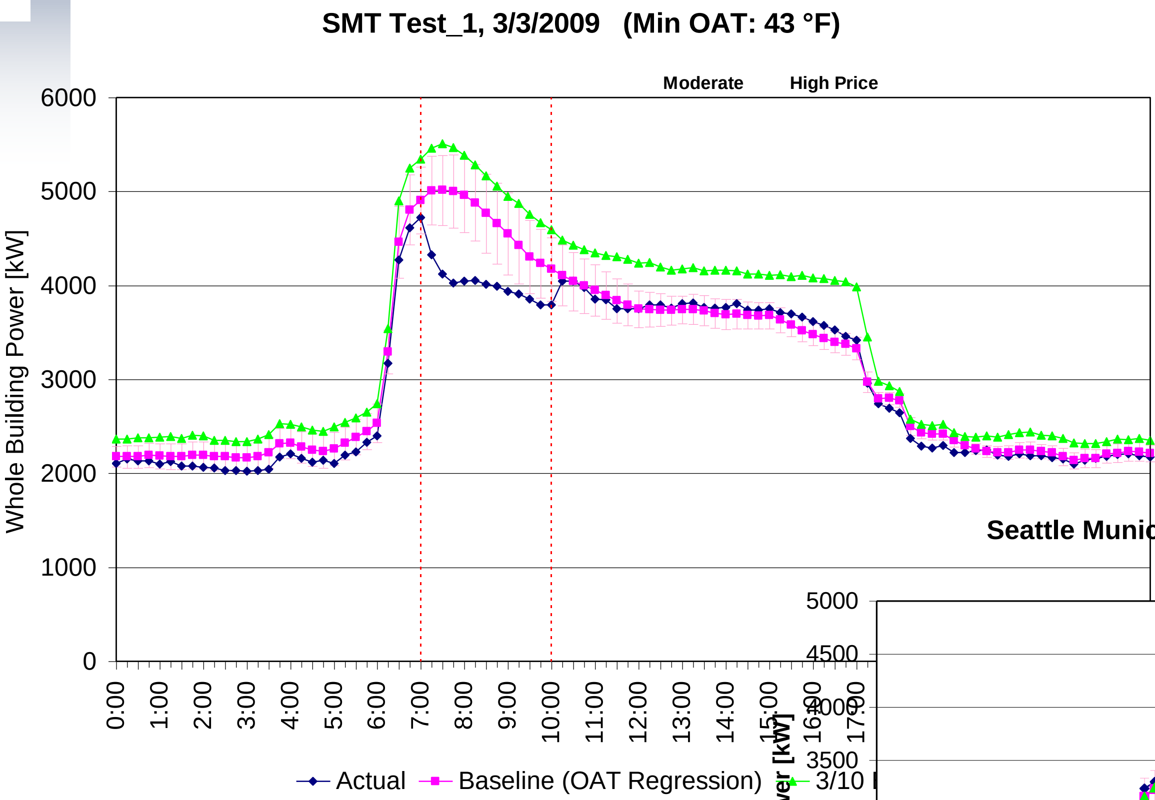


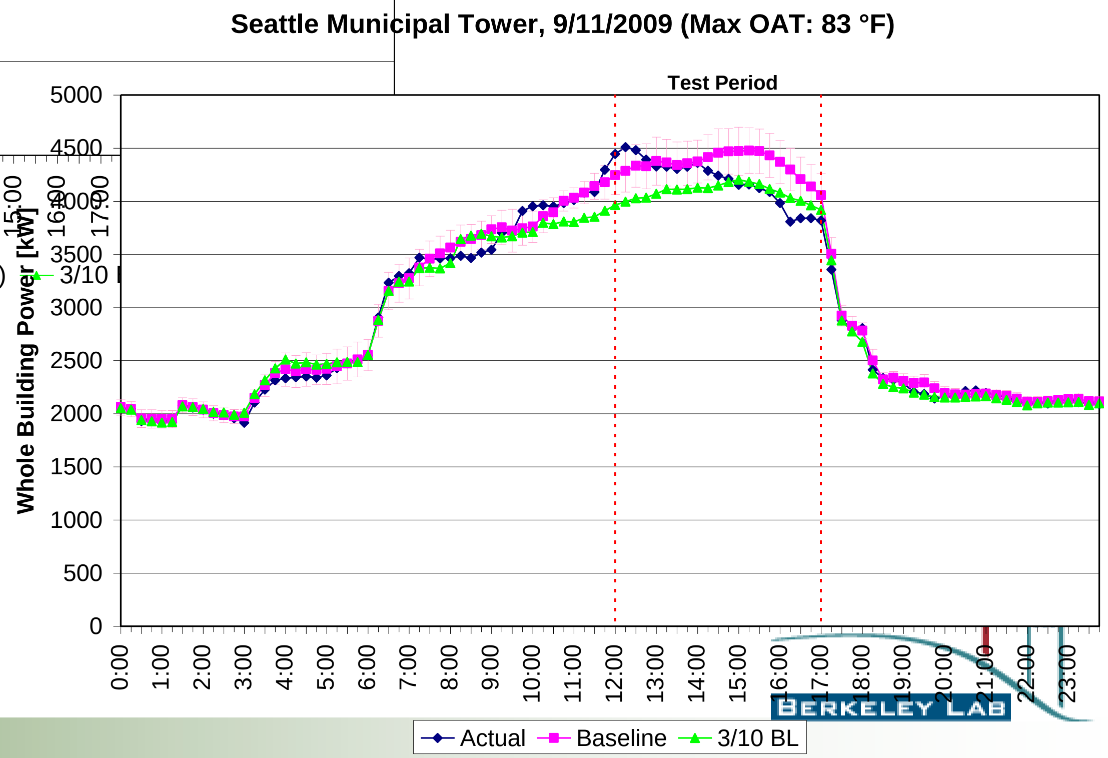


Cumulative Shed on 7/9/08



Demand Profiles from Test Events





BERKELEY LAB

Technical Coordination Concept - Automation

- Initially hand-holding customers through the automation process including DR strategy development and technology integration done by LBNL researchers.

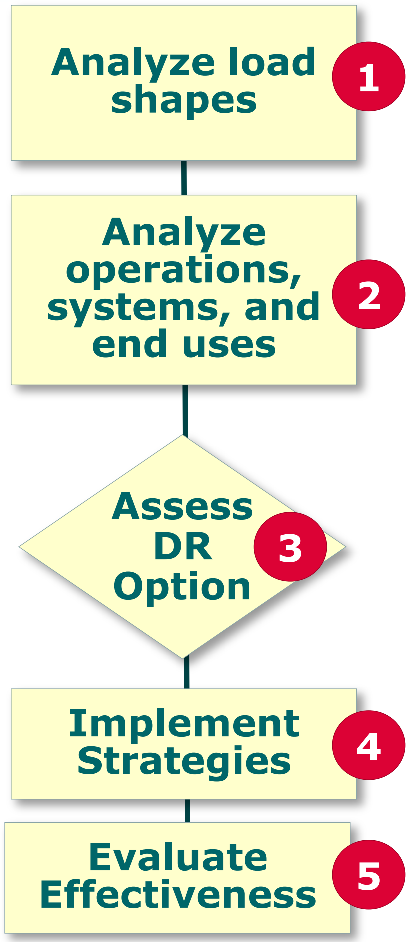
- Identified as an important role for successful commercialization.

- Control vendors identified as ideal candidates.

- Tested with the Demand Response Integration Services Company (DRISCO) concept in 2006

- Utilized in 2007 Auto-DR (Hands-on vs. Hands-off)

DR Enablement Process



Historical data used for various purposes:

1. Visual analysis
2. Develop Load Statistical Summary
3. Evaluate Load Variability and Weather Sensitivity

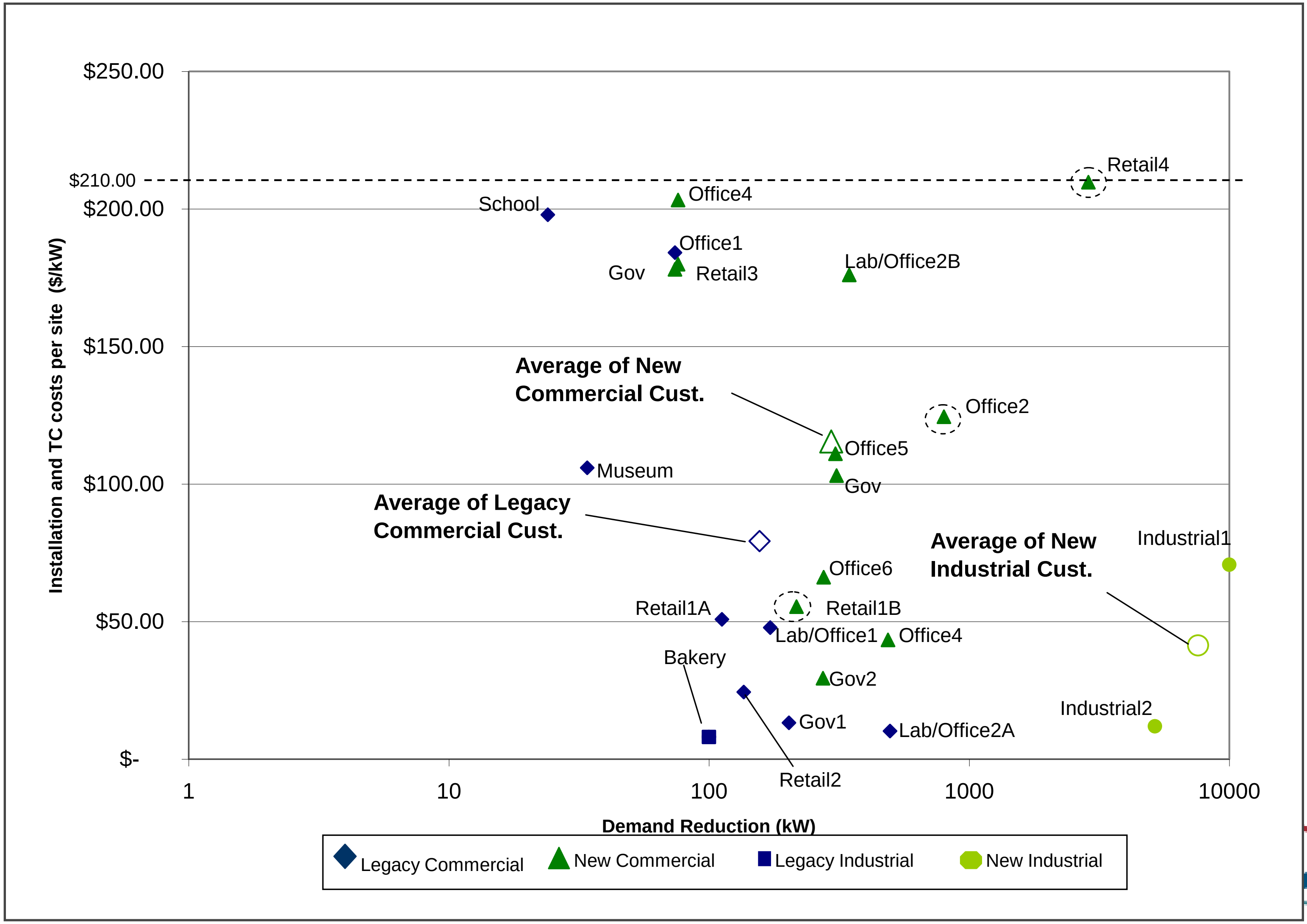
Collect information on end uses, systems, controls and operations

What kind of DR program works for the facility? Mapping load shapes onto rates and programs

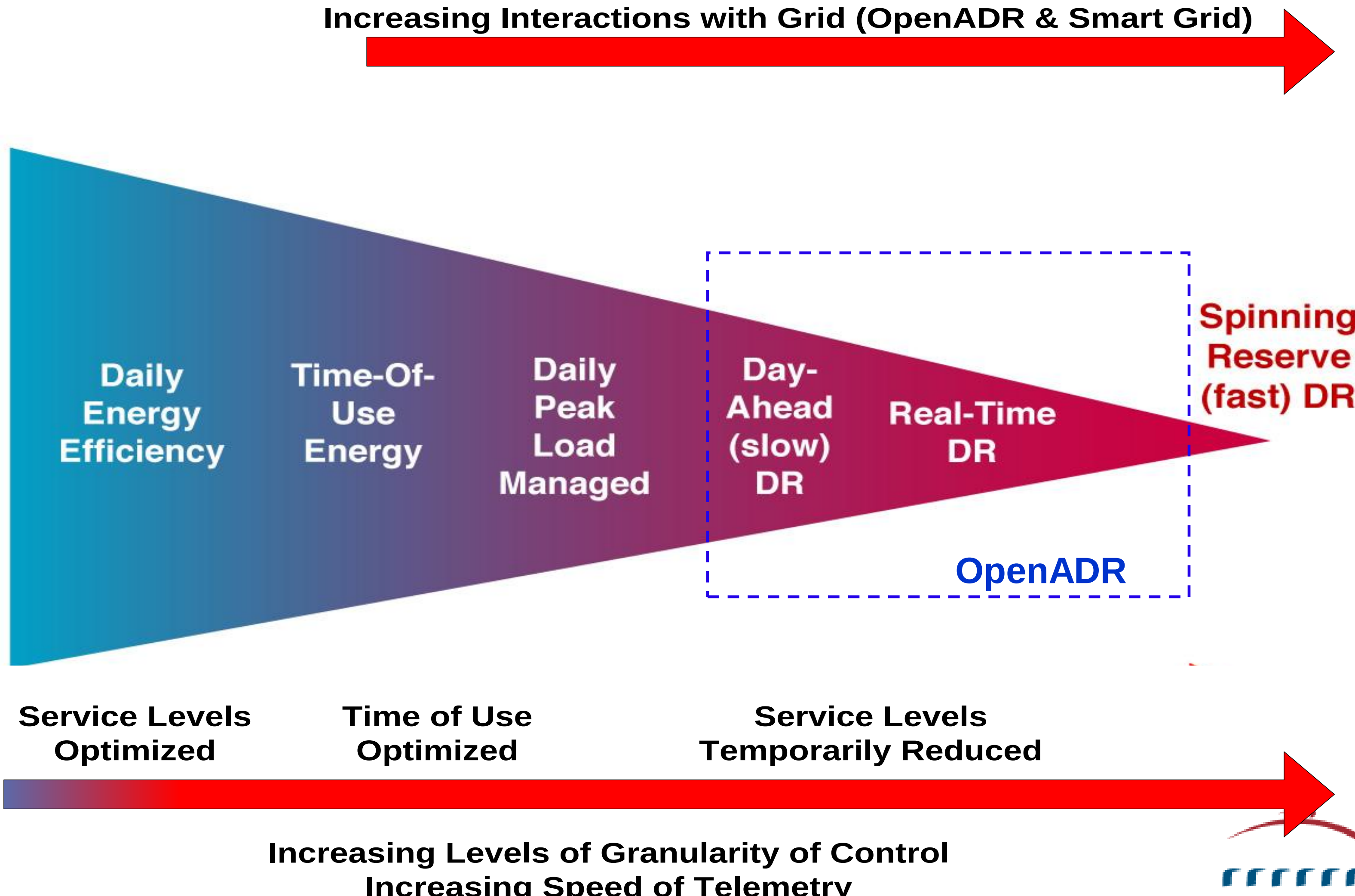
Semi- or fully-automated

Calculate shed - is it acceptable? Variable?

Installation and TC Costs for 2007 AutoDR



Demand Side Management and Automated DR Future

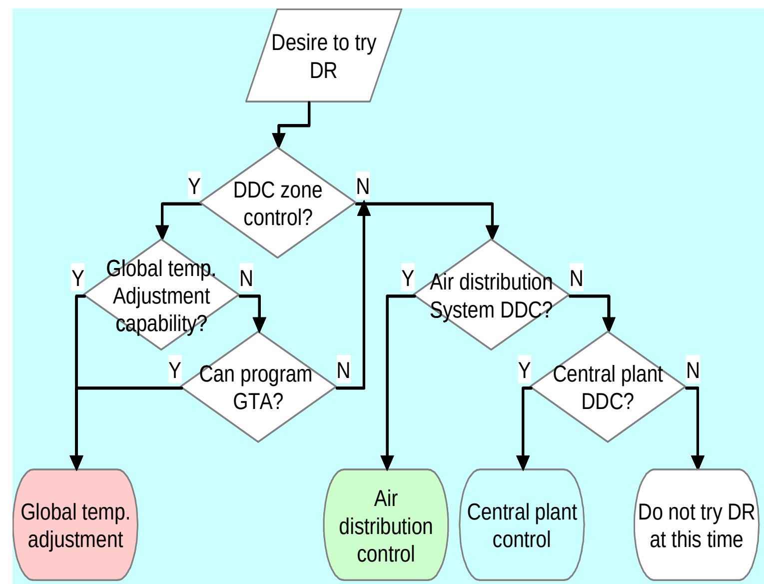


BERKELEY LAB

Linking DR and Energy Efficiency

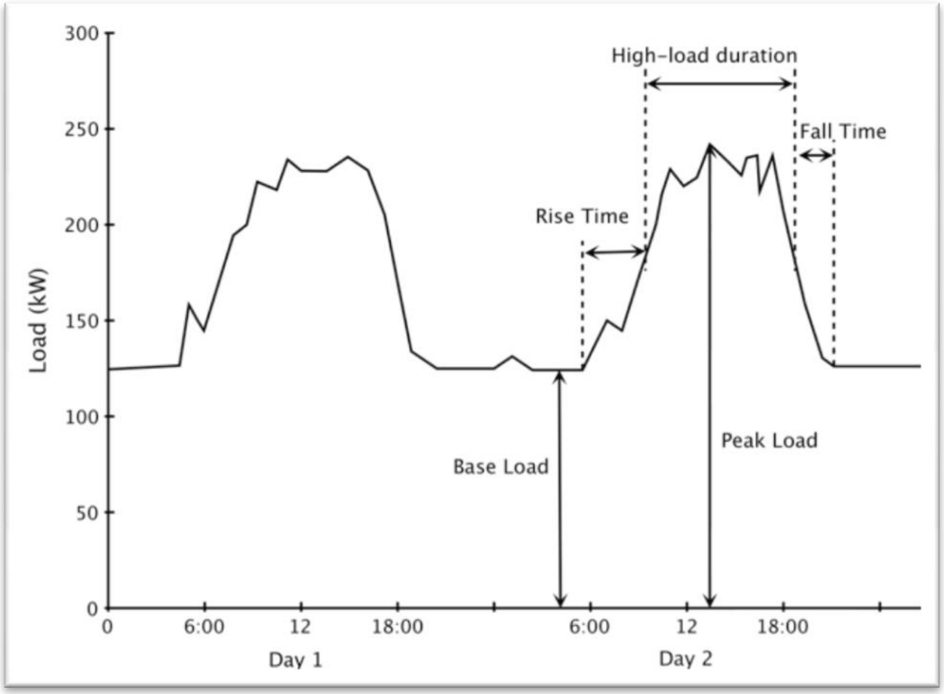
Ideal start - good commissioning, retro-commissioning, advanced/new controls

- ❑ **HVAC -** Direct digital control (DDC) global temperature adjustment
  - In process for California Building Code
  - Closed loop
- ❑ **Lighting Continuum** - Zone Switching, Fixture Switching, Lamp Switching, Stepped Dimming, Continuous Dimming
- ❑ **Maybe you "can" use a strategy every day?**



Parameters for Evaluating Load Shapes – also useful for Retro-commissioning

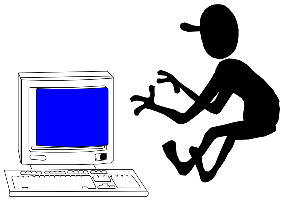
- Near-Base Load (kW): 2.5th percentile of daily load.
- Near-Peak Load (kW): 97.5th percentile of daily load.
- High-Load Duration (Hours): Duration for which load is closer to near-peak load than to near-base load.
- Rise Time (Hours): Duration for load to go from near-base load to the start of the high-load period.
- Fall Time (Hours): Duration for the load to go from the end of the high-load period to the near-base load.

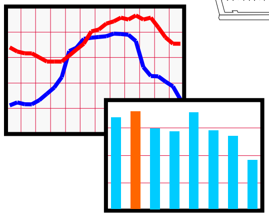


BERKELEY LAB

Future Directions
DR strategies as a "Modes" in Optimized Control

- Orchestrate modes using schedules, signals, optimization algorithms:
  - Occupied/Unoccupied
  - Maintenance/Cleaning
  - Warm up/Cool down
  - Night purge/Pre-cooling
  - Low power DR mode



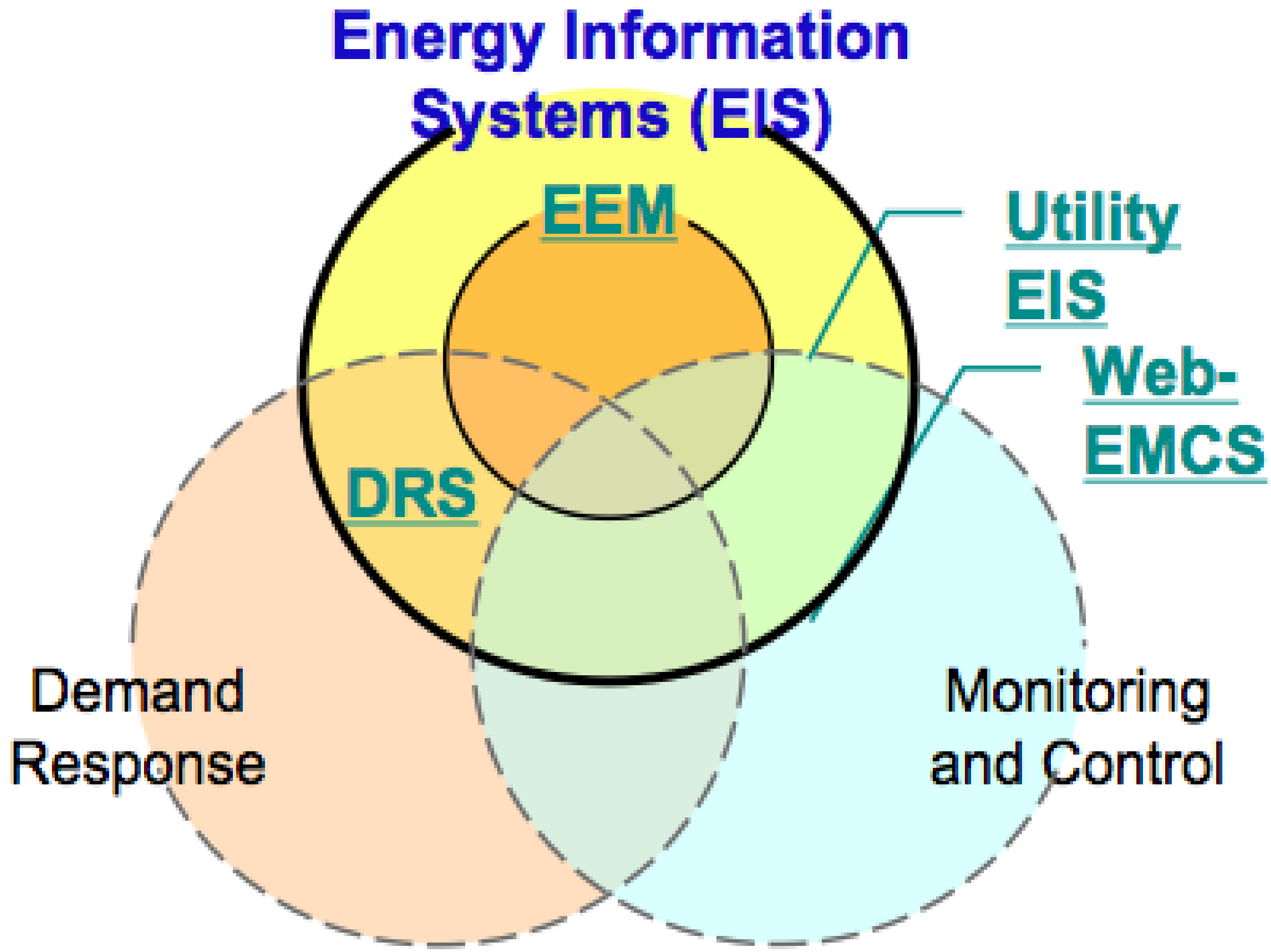


- Intelligence needed for decision making
- Financial feedback systems need to present operational value
- Embed DR communications client in EMCS – work toward codes, support BACnet and LON interoperability

See http://drrc.lbl.gov/ for publications

BERKELEY LAB

Summary of EIS State of Technology



* Vendor list and evaluations can be downloaded from: http://eis.lbl.gov/

Potential Collaboration– Web-Based Energy Information Systems

Problem Optimal energy performance requires high quality, granular building performance data, more timely analysis than monthly utility bills

Data → Information → Action

Projects

1. Review of Energy Information Systems (CEC Funded, complete)

- Defined a characterization framework
- Evaluated state of the technology – 30 EIS
- Conducted user case studies to identify energy savings

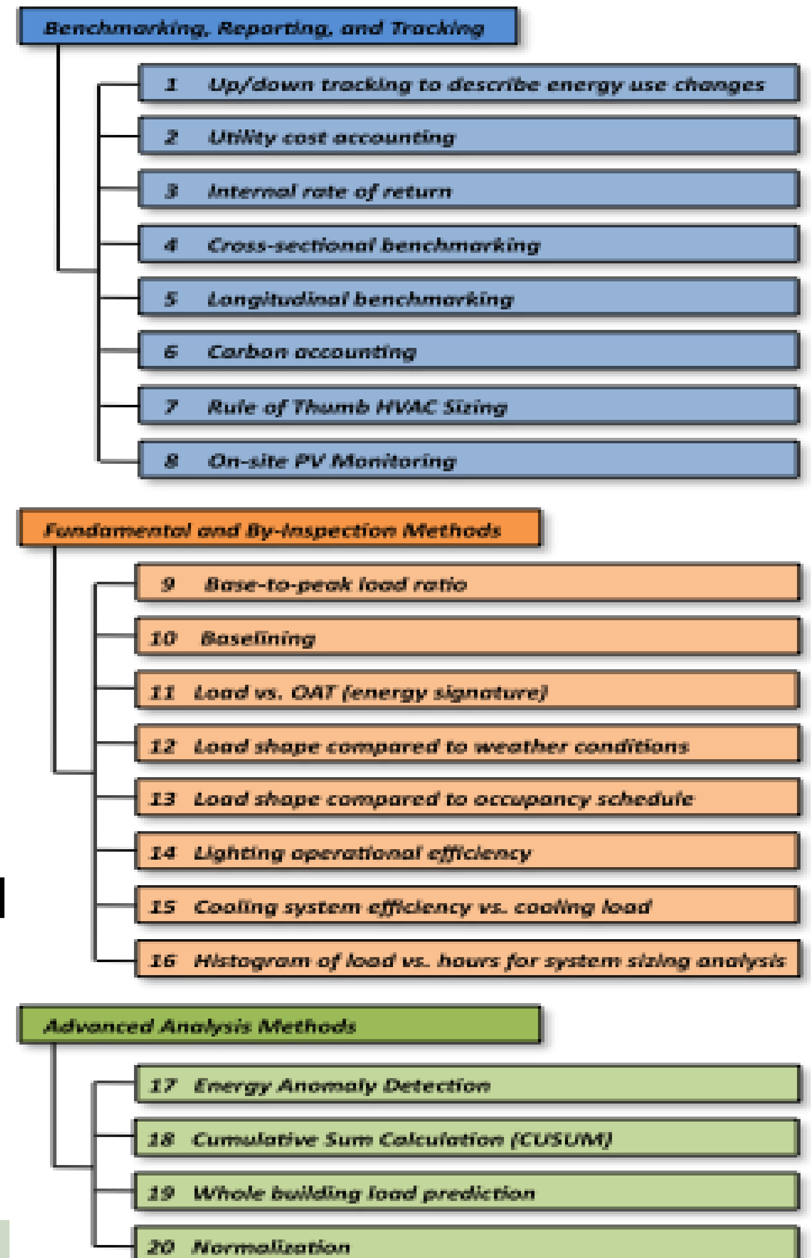
2. Handbook on Energy Information Applications (DOE Funded, underway)

- Technical Advisory Group to select key applications
- Evaluated state of the technology
- Conducted user case studies to identify energy savings

38

Results and Next Steps

- Shown how key owners use EIS-need to disseminate best practices and accelerate adoption
- Strong interest in movement toward utility incentives, developing specification for DOE Commerical Building Energy Alliances.
- Partnering/interest from vendors, Consortium for Energy Efficiency, USGBC, Utilities, ASHRAE Standard
- Web site: eis.lbl.gov



Responsive Buildings